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METHANE ACCUMULATIONS FROM INTERRUPTED VENTILATION

WITH SPECIAL REFERENCE TO COAL MINES IN ILLINOIS AND INDIANA

BY

HOWARD I. SMITH

AND

ROBERT J. HAMON

ILLINOIS COAL MINING INVESTIGATIONS COOPERATIVE AGREEMENT

(This report was prepared under a cooperative agreement with the Illinois State Geological Survey and the Engineering Experiment Station of the University of Illinois)

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PREFACE.

When the coal-mining industry of this country began to appreciate that disastrous explosions in bituminous coal mines were due to coal dust rather than to firedamp or methane in the mine air, various proposals were made to lessen the danger. As these explosions were more frequent in cold weather many men reasoned that if the cold air could be cut off there would be less danger of such explosions and this fallacious idea advanced so far in Iowa, Kansas, and parts of the interior coal fields that it became the practice to shut down the fan at shot-firing time. This practice continued in spite of many shot firer's explosions that occurred when the fan was shut down. So strongly was this view held in certain parts of the country that not until tests were made, at the experimental mine of the bureau, in starting coal-dust explosions, both in a quiet atmosphere and in a fresh current of air—with results that showed that shutting down the current had no effect—was it more generally accepted that shutting down the fan was of no advantage.

On the other hand, the Bureau of Mines investigators urged as strongly as they could, that the shutting down of fans in mines that made any appreciable amount of inflammable gas very greatly increased the hazard of such explosions, because actual experience at the experimental mine showed that for each percentage of natural gas (chiefly methane) that was added to the air the inflammability limits of a coal-dust mixture brought up into a dust cloud were raised. In other words, the risk was greatly increased. Nevertheless the idea still persisted, not only at mines where no appreciable amount of methane was made and shutting down the fan did not make so much difference, but also at mines making a considerable amount of gas, in Kansas, Oklahoma, and Indiana.

Opportunity was taken through cooperation with officials of certain mines in Illinois and Indiana to conduct some experiments on the effects of methane accumulations when the fan or ventilating current was stopped for a while. This work was undertaken by Howard I. Smith, mining engineer, then of the Bureau of Mines, in the cooperative agreement which the bureau has with the Illinois Geological Survey and the University of Illinois. Mr. Smith was assisted by Robert J. Hammond, chemist.

As naming the particular mines or mining companies is not deemed expedient, credit can not be given for the cordial support given by

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the various mine operators. After completing the field investigations Mr. Smith prepared a report, the essential features of which are presented in this publication. Subsequently, Mr. Smith entered private work, and the final preparation of the manuscript was placed in the hands of E. A. Holbrook, the present superintendent of the Urbana station of the Bureau of Mines, who was assisted by W. B. Plank.

The manuscript has been reviewed and approved by the representatives of the cooperating body, the State of Illinois, Prof. H. H. Stoek, head of the mining department of the university, and Prof. C. M. Young in the mining department.

It is believed that the data collected fully demonstrate the risk in the stoppage or slowing down of mine fans at shot-firing time, and it is expected that similar investigations will be conducted elsewhere as opportunity presents. Consequently, this paper may be considered as a report of progress.

G. S. Rice,
Chief Mining Engineer.

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METHANE ACCUMULATIONS FROM INTERRUPTED VENTILATION, WITH ESPECIAL REFERENCE TO COAL MINES IN ILLINOIS AND INDIANA.

By Howard I. Smith and Robert J. Hamon.

INTRODUCTION.

The Bureau of Mines has entered into a cooperative agreement with the Illinois State Geological Survey and the Engineering Experiment Station of the University of Illinois with the object of studying the mineral resources, mining practices and conditions in the State of Illinois, and of publishing the results in order to forward the conservation of life and the encouragement of a more economic development of natural resources.

This technical paper is a result of the cooperation and is a part of a general study of mine air now in progress. It reports a study made by the bureau in coal mines in southern Illinois and in Indiana for the purpose of obtaining definite information on methane accumulations that result from interrupted ventilation. Nothing has been published previously about the rate at which methane accumulates in a mine during periods of disturbed ventilation.

The mining laws of many States provide that when ventilation is interrupted in mines in which methane is generated the men in the workings affected, especially if open lights are used there, shall be gotten out as quickly as possible. There are many mines or sections of a mine in which only a small quantity of methane is generated and where, under regular conditions of ventilation, it is so diffused with the air as not to be detectable with a safety lamp. These places are considered nongaseous and often no concern is felt if the ventilation is interrupted even for several hours at a time. That locally in such mines there may be dangerous accumulations of methane within a short time if the air current is stopped is indicated by the tests described in this paper.

In three mines, two in southern Illinois and one in Indiana, samples of mine air were collected and analyzed from working places where no methane had been reported by the mine examiner. By stopping the air current during the tests any accumulation of methane through this interrupted ventilation was detected. The results show a

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surprisingly rapid increase in methane content of the mine air, enough to aid greatly the propagation of a coal-dust explosion, and to indicate that within a few hours an inflammable mixture of air and methane may accumulate.

It is or has been recently the practice at some coal mines in the central district and in many mines in other parts of the United States to slow or to stop the fan preceding and during shot firing. The Bureau of Mines [a] has found that the presence of only one or two per cent of methane in the air of a mine increases decidedly the liability to propagation of an explosion that may originate from a blown-out shot or other cause. It is felt, therefore, that the practice of slowing or stopping the fan is hazardous, at least in mines where any methane is generated.

The practice of reducing ventilation at shot-firing time has been defended on the grounds that lessening the volume or current of the air entering the mine lessens the liability of a gas or a dust explosion, that less dust is in suspension, and that without the ventilating current the amount of oxygen in the mine air decreases and the percentage of carbon dioxide increases sufficiently to lessen the hazard of a gas or coal-dust explosion. Although it is not the province of this paper to disprove these contentions for all mines and mining conditions, the tests outlined, supplemented by investigations of explosions, show that slowing the fan during shot firing, or any other condition that allows methane to accumulate, is dangerous practice. Ways in which methane accumulations may be prevented are suggested on subsequent pages.

The terms "methane" and "gas" are used interchangeably in the paper to designate marsh gas (CH_4), the inflammable gas commonly generated in coal mines. The term "fire damp" refers more properly to an inflammable mixture of methane and air. The term "stratification of gas," as used in this paper, denotes accumulations of methane in the absence of a ventilating current; then, owing to the low rate of diffusion in still air, the gas, being only 0.55 times as heavy as air, tends to rise through the air more rapidly than it is diffused and to become concentrated along the roof.

ACKNOWLEDGMENTS.

Acknowledgments are due J. E. Jones, mine inspector of the eleventh district of Illinois; Michael Scollard, chief deputy mine inspector of Indiana, and J. R. Fleming, assistant mining engineer of the Bureau of Mines, all of whom assisted in the field work for this report. G. S. Rice, chief mining engineer of the Bureau of Mines, planned the investigation and with F. W. De Wolf, director of the Illinois Geological Survey, and H. H. Stoek, professor of

[a] Rice, G. S., and Jones, L. M., Methods of preventing and limiting explosions in coal mines. Tech. Paper 84, Bureau of Mines, 1915, p. 7.

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mining engineering at the University of Illinois, reviewed the report and gave constructive criticism. The analytical work was done in the laboratory at Urbana, Ill., equipped and maintained by the Illinois State Geological Survey and the mining department of the University of Illinois under the terms of the cooperative agreement.

OCCURRENCE OF METHANE IN COAL MINES.

There is no relation between the volume of methane given off in a coal mine and the chemical composition of the coal, for both anthracite and bituminous coal mines alike may produce methane. Some of the most gassy mines are in the anthracite fields, and although many bituminous mines are gassy, practically no methane is found in the air of the mines in a few of the bituminous coal fields. Even for the same coal bed the volume of methane given off varies widely in different districts.

A number of coals of widely varying types from different States were tested to determine the quantity of methane evolved at ordinary temperature and pressure. Of these, the coal from southern Illinois mines produces the greatest volume, 0.67 liter of methane from 1 kilogram of coal in 50 days.[a] In experiments conducted by Parr and Barker [b] as much as 30 cubic centimeters of combustible gas was given off for each 100 grams of fresh coal drillings from an Illinois mine. No relation, however, exists between the quantity of methane known by experiment to be in a coal and the amount that is actually given off in mining. A number of factors influence the amount liberated in the mine, among which are the extent to which the methane that has escaped from the coal is held in cracks, fissures, and other open spaces, and the pressure developed by the gas in the coal. Often these factors are related to the depth of the seam below the surface and to the character of the rock strata overlying the coal.

Andros [c] has called attention to the frequency with which mines worked in the Nos. 5 and 6 coal seams in the southern part of Illinois, especially east of the Du Quoin anticline, are menaced by the presence of methane as is attested by the number of gas explosions that have happened there. Darton [d] found methane in the upcast air from nearly all the mines tested in these districts, and further noted the irregularity of the methane emanations in different sections of the same mine. Similar conditions are found in many mines in western Indiana where the same seams are worked. Under regular working conditions and normal speed of fan, the methane content of the mine air is so low that the miners in these districts use open lights

[a] Porter, H. C., and Ovitz, F. K., The escape of gas from coal: Tech. Paper 2, Bureau of Mines, 1911, p. 11.

[b] Parr, S. W., and Barker, Perry, Occluded gases in coal, Bull. 32, University of Illinois Eng. Exp. Sta., 1909, p. 20.

[c] Andros, S. O., Coal Mining in Illinois: Bull. 13, Cooperative Agreement, 1915, p. 154.

[d] Darton, N H., Occurrences of explosive gases in coal mines, Bull. 72, Bureau of Mines, 1915, p. 21.

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almost universally. That methane does sometimes accumulate, unknown by the workmen, even to form an inflammable mixture is shown by the following accidents investigated in these districts.

ACCIDENTS PROBABLY CAUSED BY EXPLOSIVE MIXTURES OF METHANE AND AIR.

EXPLOSIONS IN SOUTHERN ILLINOIS MINES.

Explosions in five mines in southern Illinois within a period of 12 months in 1914–15 were officially reported as having originated from open lights coming in contact with bodies of gas. Investigations showed that coal dust played a prominent part in extending these explosions. There resulted 74 deaths and numerous injuries; in addition, many miners not injured were exposed to grave danger. The mines were regarded as being modern in every respect. The cause of all the explosions was the ignition of a local accumulation of methane at or near the working places or in an entry by open lights carried by miners. At these mines it is the practice to withhold the miner's check when his working place has been found unsafe; the miner waits either until the place is made safe or until he is assigned to another working place. In none of these explosions were the checks withheld for the places where the explosions originated. Before one explosion, according to evidence given at the coroner's inquest, gas had been detected by the mine examiner, but not in sufficient quantity to be considered dangerous. Before all the explosions, according to the testimonies of witnesses, the methane must have accumulated suddenly.

At a mine in Christian County, Ill., the fan was shut down for repairs from 8 a. m., Sunday, until 4 p. m., Monday. According to the testimony it was an exhaust fan, and had been running only an hour when the night crew entered the mine, although no examination had been made for methane. The crew traveled on the intake about 5,000 feet from the shaft to within about 460 feet of the face of a cross entry, where their open lights ignited a body of gas. All the men in the party were killed or injured. The gas was believed by the investigators to have originated in closed workings and to have leaked out into the entry while the fan was stopped; then, after the air current was reestablished, to have moved forward about 1,500 feet without becoming diluted below the ignition point.

EXPLOSIONS IN INDIANA MINES.

In Indiana, in 1914–15, especially in Vermilion and Vigo Counties, there were many mine explosions initiated by blasting with black powder, where the lists of killed and injured were limited solely by the shot firers being the only men in the mine at the time. In many of these mines the coal is shot from the solid, and at most of them it is the practice to slow or to stop the fan before and during shot

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firing. Although the definite statement can not be made that the presence of methane was a contributory cause of these explosions, the probability that this was the case is brought out by the analyses of methane samples taken afterwards by the authors in these mines, by the conclusions of the tests on methane accumulations given on pages 29–31, and by the fact that many men have been burned in the mines in this district as a result of their lights coming in contact with local bodies of gas, even though no explosion took place.

At one mine in Vermilion County, where shot firers had been injured by explosions, so little attention was given to gas that fire bosses were not employed to examine the mine before the men went to work in the morning. The shot firers here insisted on having the fan slowed for two hours before shot-firing time. The mine was relatively new and the ventilation good when the fan ran at normal speed. However, even under the regular conditions of ventilation and operation, samples of air collected from four places in the mine showed the methane content following:

Methane in mine air from a mine in Indiana.

Location.	Roof samples.		Samples across entry.	
	Laboratory No.	Percentage of methane.	Laboratory No.	Percentage of methane.
Entry No. 1	U. 480	0.19	U. 481	0.12
Entry No. 2	6039	.20	6043	.15
Entry No. 3	6041	.32	6042	.13
Entry No. 4	.....	.....	6047	.13

The roof samples represent the composition of the mine air about 2 inches from the roof, near the face, in different entries. The samples taken across the entries at the same places were from midway between the floor and the roof, 3 feet from the face, and 1 to 2 feet from the ribs. The analyses prove that considerable methane was being given off into the mine.

In a second mine in Vermilion County, in which it is the practice to slow the fan while shooting and where a number of shot firers had been killed or injured, samples of mine air were taken at six different working places while the fan was running at normal speed. The detailed analyses follow:

Methane in mine air from a second Indiana mine.

Location.	Roof samples.		Samples across entry.	
	Laboratory No.	Percentage of methane.	Laboratory No.	Percentage of methane.
Entry No. 1	6034	1.42	6033	1.25
Entry No. 2	6035	2.86	6036	1.43
Entry No. 3	6037	3.13	6181	.78
Entry No. 4	U. 704	2.76	6190	1.05

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These samples are from the faces of entries where men were working with open lights at the time. One sample analyzed 3.13 per cent methane, and in only one sample was the methane content below 1 per cent.

In a third mine in Vermilion County several shot firers had been killed at different times. They had insisted that the fan be slowed while they were at work. Two samples of the mine air were collected in an entry at a later date and about two hours after the day shift had entered the mine. The analyses (samples U. 303 and U. 305) showed 0.58 and 1.10 per cent of methane, respectively.

In a fourth mine in Vermilion County, two explosions occurred within a month during shot firing. In the first, one shot firer was killed and in the second the shot firer was rescued after being overcome. The mine is equipped in a modern manner and has been in operation only three or four years. It was the practice at this mine before shot-firing time to slow the fan from a normal speed of 90 r. p. m. to 45 r. p. m. and at the same time open the explosion doors at the top of the air shaft, thus stopping all excepting the natural ventilation. This interruption of ventilation regularly lasted about three and one-half hours each day, and on the days of both of the explosions the interruption had been in effect about two and one-half hours when the explosions happened. The first explosion, which was the more severe, started at the face of a stub entry and affected the entire panel with 14 rooms driven off each side. A sample of air (No. 7620) taken at the face of this entry a few days after the explosion and after the ventilation had been restored fully, analyzed 1.20 per cent methane.

In a mine in Sullivan County, in which it is the practice for the shot firers to have the fan slowed before shooting, two explosions at shot-firing time happened within six weeks. The second one, which killed two men, originated in an entry that was constantly wet at the face and had its floor for some distance from the face thoroughly wetted with water that leaked from the car used to take away the water that collected at the face. It would seem that dust could not have propagated an explosion originating from a blown-out shot at this place. A sample of air (U. 470) collected in the entry near the origin of this explosion and while the fan was running at normal speed, analyzed 0.54 per cent methane.

TESTS TO DETERMINE RATE OF METHANE ACCUMULATION WHEN VENTILATION IS INTERRUPTED.

MINES CHOSEN FOR TESTS.

In order to learn the actual mine-air conditions when ventilation is interrupted or stopped in a mine, and especially to obtain data regarding methane accumulation or increase in the mine air, a series of tests was conducted in three mines—two in southern Illinois, and one in Indiana. Of the mines chosen in Illinois, the first was a well-

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developed mine in Montgomery County, and the second a comparatively new mine in Franklin County. The Indiana mine was in Vigo County. Methane is generated to some degree in all these mines although open lights are used altogether by the miners.

All the places in the mines selected for tests were at or near comparatively fresh working places where audible gas feeders showed that methane was being given off in appreciable quantities. No methane had been reported by the fire boss in any of these places, and the amount in the air under ordinary mine-ventilating conditions is therefore assumed to have been too small for the mine examiner to detect with his naphtha-burning safety lamp.

COLLECTION AND ANALYSIS OF SAMPLES.

In each mine samples of the air were taken regularly for several hours in a selected place, both under the regular ventilation conditions and with the fan slowed or stopped and ventilation therefore interrupted. After the fan had stopped there was a very slight air current or natural ventilation in the regular direction at the places being tested. This was so feeble that its velocity could not be measured with an anemometer, but was detected by shaking chalk dust in the air and observing the direction of its movement.

Samples of the air were taken at the roof, floor, and across the middle of each section, which made possible the determination of any differences in the composition of the air from bottom to top of the section. Most of the samples were collected in 250-c. c. vacuum bottles each fitted with a capillary tube that was sealed by fusing the end. When this seal is broken, the vacuum in the bottle causes it to fill with the outside air in a time of less than two seconds. Then the tube is resealed by covering and pushing into the end of the tube "universal" wax, composed of equal parts of beeswax and Venice turpentine.

For collecting the roof and floor samples, the bottles were held stationary, but for collecting the samples at the middle of a section, the bottle was moved swiftly from left to right as soon as opened so as to get a representative sample of the air about 3 feet above the floor and parallel to the face. This middle or center sample shows the condition of the air at about the height at which the miner normally works. Sometimes, as when a more general sample across a section was desired, air was pumped by means of a rubber bulb into a patented stopper bottle of about 360-c. c. capacity.

The air samples were shipped to Urbana, Ill., and analyzed there by one of the authors in the gas laboratory maintained at the University of Illinois under the terms of the cooperative agreement. The gas apparatus used was the Haldane, as modified by Burrell, fitted with a Winkler pattern slow-combustion pipette, and has been described fully in Bureau of Mines Bulletin 42.[a]

[a] Burrell, G. A., and Seibert, F. M., The sampling and examination of mine gases and natural gas, Bull. 42, Bureau of mines, 1913, p. 38.

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TESTS IN A MINE IN MONTGOMERY COUNTY, ILL.

The first series of air samples was collected in a mine in Montgomery County, Ill., working the No. 6 seam. The mine is opened by shafts about 400 feet deep, is worked by the room-and-pillar system, and is ventilated by a blower fan. On the day of the tests the mine was idle, but the fan was running at normal speed. Ordinarily open lights are used by all the men in the mine.

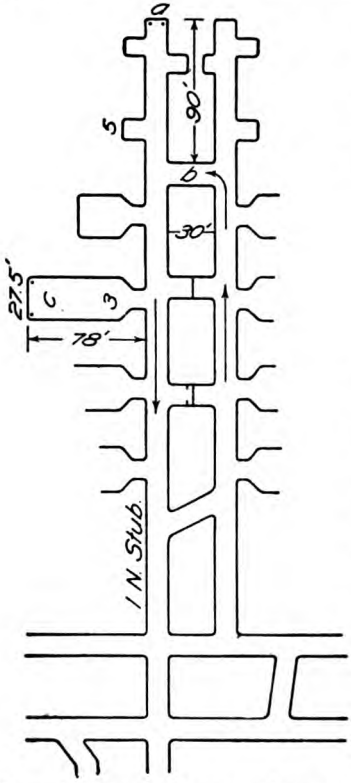

FIGURE 1.—Plan of stub entry and rooms in a mine in Montgomery County, Illinois, showing where air samples were collected.

Figure 1 shows a plan of the stub entry and rooms where the air samples were collected in this mine. The first series of samples were taken at the entry face marked *a*, the second in the crosscut *b*, and the third at the room face *c*.

SAMPLES FROM AN ENTRY FACE.

The face of the first north stub entry, marked *a*, was about 10,400 feet from the down-cast shaft as measured along the course of the air current indicated by the arrows, and 6,000 feet inby from the first working place on this air split. It was 90 feet inby from the last open crosscut *b* as the crosscut to the parallel entry about 30 feet from the face had not been holed through. On the left a room neck had been turned about 20 feet from the face. The entry was about 9 feet wide and 5.5 feet high. At the face there was a pile of coal, which had been broken down, extending to within 30 inches of the roof. Several gas feeders could be detected near the face of the entry, although no methane had been reported there on that day by the mine examiner. The authors, using a flat-wick Koehler safety lamp were able to obtain a small gas cap near the roof.

The first samples were taken at 1.50 p. m., and the sampling was repeated regularly every half hour until 6.30 p. m. Each lot consisted of three samples, (1) a top sample taken on the left side, 18 inches from the face of the entry and 2 inches from the roof; (2) a center sample taken across the entry 6 feet from and parallel to the face and 3 feet from the floor; (3) a bottom sample on the right side

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6 feet from the face and close to the pile of coal there, and 2 to 6 inches above the floor.

At 2 p. m. immediately after the first sampling, the fan was stopped, but was started again at 4.30 p. m. Thus the samplings cover periods when the entry ventilation was normal, when it was interrupted completely, and when it was restored. Just before the fan stopped 4,300 cubic feet of air per minute were passing through the last open crosscut *b*. To make possible a velocity reading on an anemometer, the measurement was taken in a cross section reduced to 30 square feet. The corrected air velocity in the crosscut was 145 feet a minute, the temperature was 65.5° F., and the relative humidity 97 per cent.

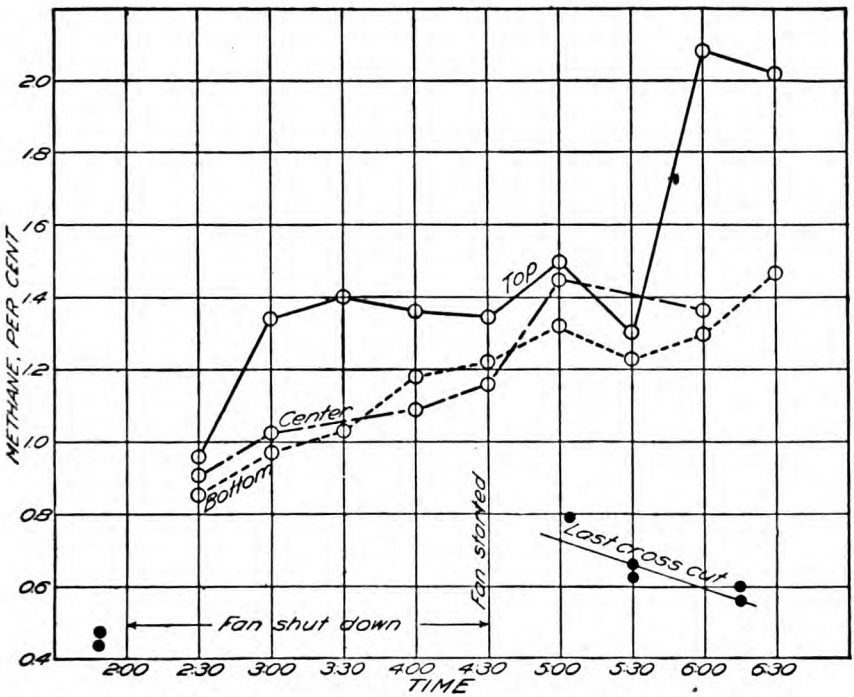

FIGURE 2.—Curves showing rates of methane accumulation at face of stub entry.

The analyses of all the mine air samples taken in this stub entry are given in Table 1, following. In general, stopping the fan for two- and one-half hours did not increase the percentage of carbon dioxide in the air or decrease appreciably the percentage of oxygen. The methane content of the air, however, shows a marked increase, and to bring this out clearly Table 2, page 16, is given, which lists the percentages of methane alone according to time taken and place in the section. These methane analyses are plotted in figure 2, and show the rates of methane accumulations at the top, center, and bottom of this entry according to time and change of ventilating conditions.

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SAMPLES FROM A CROSSCUT.

To learn the condition of the air in the ventilating current entering the entry *a*, samples of the air in crosscut *b* were collected during the time of the tests in the entry. The analyses of these samples, given in Table 3, show the changes in the air in the crosscut due to the interrupted ventilation. Table 4 shows the percentage of methane in the air of this crosscut, and is derived by grouping the methane from the air samples of Table 3. These methane analyses have been added in figure 2, where they appear as the lowest points.

TABLE 1.—*Analyses of mine air samples collected at the face of a stub entry in a mine in Montgomery County, Ill., showing changes due to interrupted ventilation.*

Laboratory No.	Position in section.	Temperature, °F.	Humidity, per cent.	Barometer, inches.	Time, p. m.	Analysis of sample as received.				Analysis of sample "methane free," percentage of—		
						Carbon dioxide (CO_2).	Oxygen (O_2).	Methane (CH_4).	Nitrogen (N_2).	(CO_2).	(O_2)	(N_2).
						Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct*
U. 617	Top	.....	.....	29.80	1.50	0.65	19.22	1.03	79.10	0.66	19.42	79.92
U. 618	Center	.....	.....	29.80	1.50	.59	19.24	1.03	79.14	.60	19.44	79.96
U. 619	Bottom	.....	.....	29.80	1.50	.57	19.25	1.03	79.15	.58	19.45	.....
					[a]2.00							
U. 620	Top	.....	.....	29.80	2.30	.58	19.28	.96	79.18	.58	19.47	79.95
U. 621	Center	.....	.....	29.80	2.30	.55	19.29	.91	79.25	.55	19.46	79.99
U. 622	Bottom	.....	.....	29.80	2.30	.58	19.28	.85	79.29	.58	19.42	80.00
U. 623	Top	64.5	95	29.75	3.00	.57	19.15	1.34	78.94	.58	19.41	80.01
U. 624	Center	64.5	95	29.75	3.00	.57	19.28	1.03	79.12	.58	19.48	79.94
U. 625	Bottom	64.5	95	29.75	3.00	.57	19.30	.97	79.16	.58	19.49	79.93
U. 626	Top	65	97	29.75	3.35	.55	19.15	1.40	78.90	.56	19.42	80.02
U. 627	Center	65	97	29.75	3.35	.43	19.76	.67	79.14	.43	19.89	79.68
U. 628	Bottom	65	97	29.75	3.35	.51	19.23	1.03	79.23	.52	19.43	80.05
U. 629	Top	66	93	29.75	4.00	.53	19.13	1.36	78.98	.54	19.39	80.07
U. 630	Center	66	93	29.75	4.00	.62	19.09	1.09	79.20	.63	19.30	80.07
U. 631	Bottom	66	93	29.75	4.00	.64	19.08	1.18	79.10	.65	19.31	80.04
U. 632	Top	64.5	95	29.75	4.30	.57	19.13	1.34	78.96	.58	19.39	80.03
U. 633	Center	64.5	95	29.75	4.30	.57	19.20	1.16	79.07	.58	19.42	80.00
U. 634	Bottom	64.5	95	29.75	4.30	.57	19.18	1.22	79.03	.58	19.42	80.00
					[b]4.30							
U. 635	Top	64.5	95	29.80	5.00	.56	19.21	1.50	78.73	.57	19.50	79.93
U. 636	Center	64.5	95	29.80	5.00	.61	19.11	1.45	78.83	.62	19.40	79.98
U. 637	Bottom	64.5	95	29.80	5.00	.55	19.20	1.32	78.93	.56	19.44	80.00
U. 638	Top	64.5	95	29.80	5.25	.56	19.11	1.30	79.03	.57	19.36	80.07
U. 639	Center	64.5	95	.....	5.25	.19	20.62	.21	78.98	.19	20.66	79.15
U. 640	Bottom	64.5	95	.....	5.25	.56	19.13	1.23	79.08	.57	19.37	80.06
U. 641	Top	64.5	95	29.80	6.00	.58	18.88	2.09	78.45	.59	19.18	80.23
U. 642	Center	64.5	95	29.80	6.00	.56	19.11	1.36	78.97	.57	19.37	80.04
U. 643	Bottom	64.5	95	29.80	6.00	.58	19.14	1.30	78.98	.59	19.39	80.02
U. 644	Top	64.5	95	29.80	6.30	.55	18.94	2.02	78.49	.56	19.33	80.11
U. 645	Bottom	64.5	95	29.80	6.30	.57	19.06	1.47	78.90	.58	19.34	80.08

[a] Fan stopped. [b] Fan started.

TABLE 2.—*Percentages of methane at face of a stub entry in a mine in Montgomery County, Ill.*

Time.	Percentage of methane in section at—		
	Top.	Center.	Bottom.
1.50	1.03	1.03	1.03
2.00[a]	.....	.....	.....
2.30	.96	.91	.85
3.00	1.34	1.03	.97
3.35	1.40	.....	1.03
4.00	1.36	1.09	1.18
4.30[b]	1.34	1.16	1.22
5.00	1.50	1.45	1.32
5.25	1.30	.....	1.23
6.00	2.09	1.36	1.30
6.30	2.02	.....	1.47
Average	1.434	.99	1.16

[a] Fan stopped. [b] Fan started.

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TABLE 3.—*Analyses of mine air samples collected in last open crosscut near face of entry, in a mine in Montgomery County, Ill., showing changes due to interrupted ventilation.*

Laboratory No.	Position in section.	Temperature, °F.	Humidity.	Barometer, inches.	Time, p. m.	Analyses of sample as received.				Analysis of sample methane free.		
						Carbon dioxide (CO_2).	Oxygen (O_2).	Methane (CH_4).	Nitrogen (N_2).	(CO_2)	(O_2.)	(N_2.)
			Pr. ct.			*P. ct.*	*P. ct.*	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
U. 676	Top	65½	97	.....	1.50	0.51	19.46	0.45	79.58	0.51	19.55	79.94
U. 677	Bottom	65½	97	.....	1.50	.50	19.44	.47	79.59	.50	19.53	79.97
					[a]2.00							
					[b]4.30							
U. 678	Average	.....	.....	.....	4.50	.55	19.30	.71	79.44	.55	19.45	80.00
U 679	.....do	.....	.....	.....	5.05	.55	19.29	.79	79.37	.55	19.44	80.01
U. 680	Top	.....	.....	.....	5.30	.54	19.27	.63	79.56	.54	19.39	80.07
U. 681	Bottom	.....	.....	.....	5.30	.55	19.28	.66	79.51	.55	19.41	80.04
U. 682	Top	65½	97	29.80	6.15	.53	19.27	.58	79.62	.53	19.38	80.09
U. 683	Bottom	65½	97	.....	6.15	.53	19.33	.56	79.58	.53	19.44	80.03

[a] Fan stopped. [b] Fan started.

TABLE 4.—*Percentages of methane in last open crosscut near face of entry in a mine in Montgomery County, Ill.*

Time, p. m.	Top.	Average of section.	Bottom.	Fan, stopped or running.
1.50	0.45	.....	0.47	Running.
4.50	.....	0.71	.....	Stopped at 2 p. m., started at 4.30 p. m.
5.05	.....	.79	.....	Running.
5.30	.63	.....	.66	Do.
6.15	.58	.....	.56	Do.

DISCUSSION.

A study of the methane analyses of the air of the entry, Tables 1 and 2 and figure 2, brings out strongly the decided increase in methane content while the fan was stopped, but the results show irregularities which require explanation as follows:

The methane analyses of the samples taken at 1.50 p. m. show the normal percentage of methane in the air in the entry and the agreement of the analyses of top, center, and bottom samples indicates complete diffusion. For some unknown cause the next samples, taken ½ hour after the fan had stopped, show slightly lower methane content. From here on the methane content increases gradually until the fan was started at 4.30 p. m. Although the sampling was continued until 6.30 p. m. the methane content of the air did not decrease; in fact, at the top of the section it continued to increase rapidly. The face of this entry was, of course, 90 feet inby the last crosscut where the air was passing. Evidently it takes more time than from 4.30 to 6.30 p. m. for the restored air current to diffuse and sweep away the methane from the face of this entry.

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Individually, in each sampling after the fan stopped, the samples taken at the top of the section show the largest percentage of methane. In general the samples taken at the center show the next smaller percentage, although from 3.30 p. m. until 5 p. m. the methane content of the bottom samples was greater than that of the center samples. These results show the effect of diffusion of the gas in the air of the entry. Gas was issuing into the face of the entry from feeders at both the top and bottom, the most noticeable being at the top. When the fan was not running the gas evidently was issuing at a higher rate than admitted its diffusion in the air of the section.

The samples of air collected in the last open crosscut, Tables 3 and 4, and figure 2, compared with the air of the entry just described show different characteristics as regards methane content. The samplings at 1.50 p. m., with the fan running, give the normal methane content of this split of air at this point.. The methane accumulated while the fan was stopped reached 0.79 per cent at 5.05 p. m., half an hour after the fan had started. From this time on the methane content decreased rapidly and seemingly would have reached the normal point between 7 and 7.30 p. m. The rise for the first half hour after the fan started was due to the presence in the ventilating current of the methane that had accumulated while the fan was stopped in other workings ventilated by this same split of air. Once the ventilation was restored fully, the methane content quickly fell to the normal amount. Compared to the slowness with which the methane in the dead end of the entry was affected by restoring the ventilating current, the influence of the direct ventilation in the crosscut is emphasized.

SAMPLES FROM A ROOM.

To compare the rate of methane accumulation in a room with that in an entry under the same conditions of ventilation, the face of the third room off the same stub entry was chosen as a place for tests (see *c*, fig. 1). This room was 78 feet long, 27.5 feet wide at the face, and 6 feet high, with no cut-throughs. About 4,300 cubic feet of air per minute normally passed the mouth of the room. Ventilation of the room was by eddy currents only. Although methane had never been reported in this room by the mine examiner, its presence was indicated by audible feeders and a slight methane cap was obtained with a flat-wick Koehler safety lamp.

Air samples were taken at the face of the room at approximately the same time and under the same ventilating conditions as described for the entry sampling. The top samples were collected at the upper left corner about 2 feet from the face, 5 feet from the rib, and from 2 to 6 inches from the roof. The center samples were collected horizontally about 3 feet from and across the face. The

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lower samples were collected at the lower right corner about 2 feet from the face, 5 feet from the rib, and 2 to 6 inches from the floor.

Results of the analyses are given in Table 5, following. The carbon dioxide and oxygen contents of the air show no positive change during the test. The methane percentages are tabulated alone in Table 6. In figure 3 these methane analyses are plotted to show the rate of methane accumulations under the varying ventilating conditions.

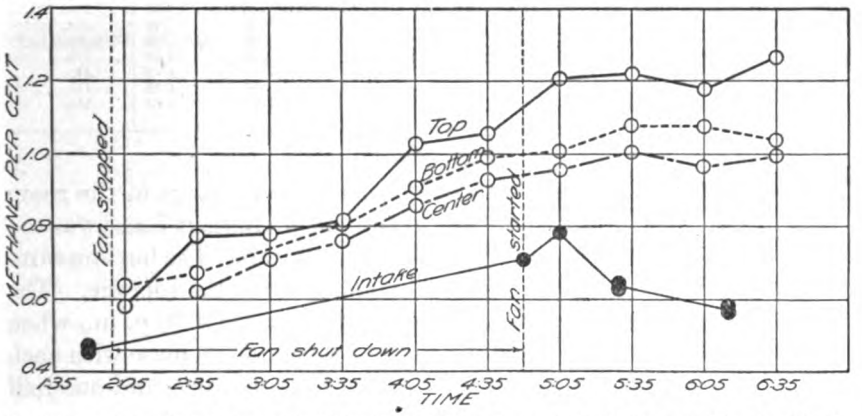

FIGURE 3.—Rates of methane accumulation at face of room in a mine in Montgomery County, Illinois.

TABLE 5.—*Analyses of mine air samples collected at the face of a room in a mine in Montgomery County, Ill., showing changes due to interrupted ventilation.*

Laboratory No.	Position in section.	Temperature, °F.	Humidity, per cent.	Barometer, inches.	Time, p. m.	Analyses of sample as received.				Analysis of sample, Methane free.		
						Carbon dioxide (CO_2).	Oxygen (O_2).	Methane (CH_4).	Nitrogen (N_2).	(CO_2.)	(O_2.)	(N_2.)
						Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
					[a]2.00							
U. 646	Top	65	97	29.75	2.05	0.56	19.35	0.58	79.51	0.56	19.56	79.88
U. 647	Center	65	97	29.75	2.05	.37	19.99	.34	79.30	.37	20.06	79.57
U. 648	Bottom	65	97	29.75	2.05	.51	19.45	.64	79.40	.51	19.57	79.92
U. 649	Top	65	97	29.75	2.35	.52	19.36	.78	79.34	.52	19.52	79.96
U. 650	Center	65	97	29.75	2.35	.59	19.31	.63	79.47	.59	19.43	79.98
U. 651	Bottom	65	97	29.75	2.35	.53	19.40	.67	79.40	.53	19.52	79.95
U. 652	Top	65	95	28.75	3.05	.53	19.31	.78	79.38	.53	19.46	80.01
U. 653	Center	65	95	29.75	3.05	.56	19.34	.71	79.39	.56	19.48	79.96
U. 654	Bottom	65	95	29.75	3.05	.18	20.73	.15	78.94	.18	20.76	79.06
U. 655	Top	66	95	29.75	3.35	.51	19.30	.82	79.37	.51	19.46	80.03
U. 656	Center	66	95	29.75	3.35	.53	19.29	.76	79.42	.53	19.45	80.02
U. 657	Bottom	66	95	29.75	3.35	.56	19.32	.81	79.31	.56	19.48	79.96
U. 658	Top	65	97	29.80	4.05	.58	19.21	1.03	79.18	.59	19.41	80.00
U. 659	Center	65	97	29.80	4.05	.57	19.27	.86	79.30	.57	19.44	79.99
U. 660	Bottom	65	97	29.80	4.05	.51	19.28	.91	79.30	.52	19.46	80.02
					[b]4.30							
U. 661	Top	65	97	29.80	4.35	.53	19.19	1.06	79.22	.54	19.40	80.06
U. 662	Center	65	97	29.80	4.35	.56	19.27	.93	79.24	.57	19.45	79.98
U. 663	Bottom	65	97	29.80	4.35	.59	19.22	.99	79.20	.60	19.41	79.99
U. 664	Top	65	97	29.80	5.05	.57	19.14	1.21	79.08	.58	19.37	80.05
U. 665	Center	65	97	29.80	5.05	.57	19.24	.96	79.23	.58	19.43	79.99
U. 666	Bottom	65	97	29.80	5.05	.56	19.26	1.01	79.17	.57	19.47	79.96
U. 667	Top	65	97	29.80	5.35	.55	19.02	1.22	79.21	.56	19.26	80.18
U. 668	Center	65	97	29.80	5.35	.57	19.11	1.01	79.31	.58	19.30	80.12
U. 669	Bottom	65	97	29.80	5.35	.60	19.22	1.08	79.10	.61	19.48	79.96
U. 670	Top	65	97	29.80	6.05	.59	19.07	1.18	79.16	.60	19.30	80.10
U. 671	Center	65	97	29.80	6.05	.55	19.16	.97	79.32	.56	19.35	80.09
U. 672	Bottom	65	97	29.80	6.05	.58	19.18	1.08	79.16	.59	19.41	80.00
U. 673	Top	65	97	29.80	6.35	.60	19.08	1.27	79.05	.61	19.33	80.06
U. 674	Center	65	97	29.80	6.35	.62	19.15	1.00	79.23	.63	19.35	80.02
U. 675	Bottom	65	97	29.80	6.35	.54	19.23	1.04	79.19	.55	19.43	80.02

[a] Fan stopped. [b] Fan started.

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TABLE 6.—*Percentages of methane at face of a room in a mine in Montgomery County, Ill.*

[Fan stopped at 2 p. m., fan started at 4.30 p. m.]

Time, p. m.	Percentage of methane in section at—			Fan stopped or running.
	Top.	Center.	Bottom.	
2.05	0.58	.....	0.64	Stopped.
2.35	.78	0.63	.67	Do.
3.05	.78	.71	.....	Do.
3.35	.82	.76	.81	Do.
4.05	1.03	.86	.91	Do.
4.35	1.06	.93	.99	Running.
5.05	1.21	.96	1.01	Do.
5.35	1.22	1.01	1.08	Do.
6.05	1.18	.97	1.08	Do.
6.35	1.27	1.00	1.04	Do.

DISCUSSION.

At the beginning of the tests the methane percentage in the room was only slightly higher than that in the entry crosscut *b* and was too small to be detectable ordinarily with a safety lamp. The bottom sample showed slightly greater methane content than the top one. The fan was stopped at 2 p. m. and from this time till 4.30 p. m., when the fan was started, the methane showed a regular increase with each sampling. Apparently it was not until 6.05 p. m., one and one-half hours after the fan was started, that the methane content of any section of the room showed a decrease.

Individually, the top samples show the greatest methane percentage in every sampling, the bottom samples the next smaller, and the center samples the smallest. The center samples show the most uniform increase, however, and if on figure 3 a straight line is drawn between the points representing the methane percentages at 2.05 p. m. and at 5.05 p. m., no intermediate point will show a variation of more than 0.02 per cent methane from the rate of uniform accumulation, a figure within the permissible limits of error of analysis. This indicates that the methane in the center of the room was thoroughly diffused. The slight irregularities in methane content of the bottom samples probably indicate disturbance of the methane currents there by the sampler's body. The top or roof samples show the tendency of the methane to stratify when the ventilation is interrupted; while the fan was stopped the methane at the roof increased from 0.58 per cent to 1.22 per cent. This is an increase of 110 per cent during a period of two and one-half hours.

The continued increase of methane percentage at the face for some time after the fan started shows the length of time necessary for the air current passing through the entry to eddy into the room and reach the face. Probably while the fan was stopped the methane stratified along the roof of the room, trailed out some distance from the face, and afterwards the entering air eddies forced this stratum back toward the face, increasing temporarily the percentage of methane there.

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TESTS AT A MINE IN FRANKLIN COUNTY, ILL.

To compare air conditions under interrupted ventilation in the Montgomery County mine just described with conditions in an exceptionally well ventilated mine with no abandoned workings, an entry in a new mine in Franklin County, Ill., was chosen for further study. This mine, in the No. 6 coal bed, is 520 feet deep and is worked in panels by the pillar-and-room system with triple main entries. Open lights are used by the miners. The samples were collected on a day when the mine was idle but when the fan had been running as usual.

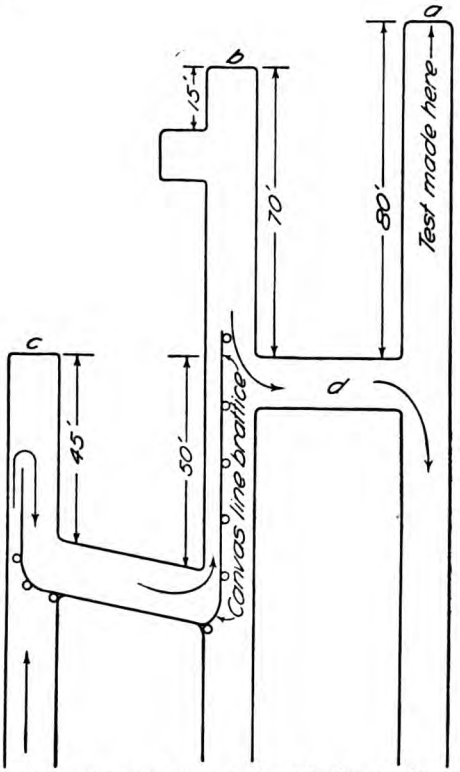

FIGURE 4.—Plan of triple entries in a mine in Franklin County, Illinois, shows where air samples were collected and course of ventilating current.

Figure 4 shows a plan of the faces of the triple entries where the samples were collected and also the course of the ventilating current there. The entries are driven on 50-foot centers, and are 12 feet wide and 6.5 feet high. The air traveled 5,000 feet from the shaft bottom to reach the place where the tests were made, but did not traverse any abandoned workings. The place chosen for test was the face of the right entry marked *a* and 80 feet inby the last open crosscut *d* through which the ventilating current was passing. A few samples were taken in this crosscut, to learn the normal methane content of the ventilating current there. Several samples for comparison were also taken at the faces of the middle entry *b* and the left entry *c*.

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The analyses and data regarding the samples collected at the face of entry *a* are given in Table 7 (page 24). The samples marked "top" were taken at the upper left corner of the entry, about 1 foot from the rib, those marked "center" were taken across entry about 3 feet from the floor and 3 feet from the face, and those marked "bottom" were taken in the lower right corner 2 feet from the face and 1 foot from the rib. The analyses and data regarding the samples collected at the faces of entries *b* and *c* and fromthe crosscut *d* are given in Table 8.

Although the tests started at 2.30 p. m. and continued until 8.20 p. m. under varying conditions of ventilation, there was no particular decrease in oxygen content of the air or increase in carbon dioxide. In order to make clear the changes in methane content during the

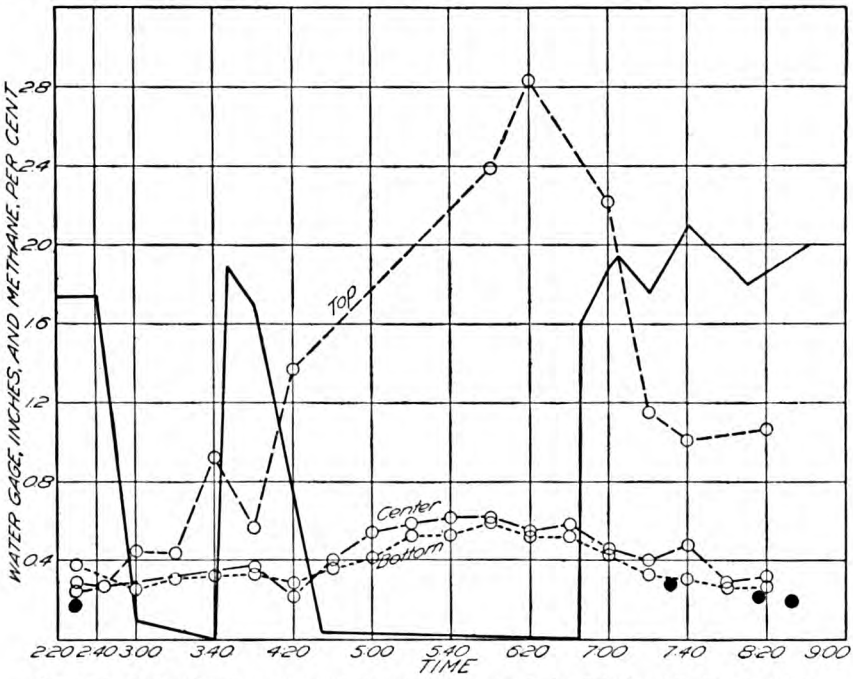

FIGURE 5.—Rates of methane accumulation at face of entry (*a*, fig. 4) in Franklin County mine. Solid heavy curve represents water gage or ventilating pressure.

tests the methane percentages listed in Tables 7 and 8 have been collected, according to time and place in the section where they were taken and are given in Table 9 (page 26). The methane percentages of this table are plotted in figure 5, which also shows the change in water gage or force producing the ventilating current during the test. These changes in ventilating current are mentioned in Table 7, under remarks, a more complete explanation being as follows:

From 1.50 p. m. until 2.40 p. m., frequent readings showed an average water gage at the fan house of 1.70 inches. At 2.40 p. m., just before the fan was stopped, an anemometer reading taken in the last open crosscut *d* near the face under test showed 7,700 cubic feet of

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air a minute in circulation there. At 3 p. m. the water gage had fallen to 0.10 inch and at 3.40 p. m. it reached zero. Owing to a misunderstanding, the engineer on the surface, after making certain repairs to the fan, started it at 3.40 p. m. and the water gage quickly jumped to 1.9 inches and at 4 p. m. registered 1.7 inches. At this time the fan was stopped and the fan doors thrown open. However, at 4.30 p. m. there was still a water gage of 0.05 inch and 1,900 cubic feet of air per minute were in circulation in the last open crosscut *d*, as measured with an anemometer after the area was reduced with canvas. The water gage did not read zero until nearly 6.45 p. m., at which time the fan was again started. The reading quickly increased to 1.6 inches and between this time and 8.30 p. m., when the readings were discontinued, varied between this point and 2.10 inches. At 7 p. m., 8,500 cubic feet of air per minute were passing through the last open crosscut *d*.

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TABLE 7.—*Analyses of mine air samples collected at the face of an entry (a, fig. 4) in a mine in Franklin County, Ill., showing changes due to interrupted ventilation.*

Laboratory No.	Time, p. m.	Position in section.	Analysis of sample as received, percentage of—				Analyses of sample methane free.			Remarks.
			Carbon dioxide (CO_2)	Oxygen (O_2).	Methane (CH_4).	Nitrogen (N_2).	CO_2.	O_2.	N_2.	
U 770	2.30	Top	0.12	20.75	0.29	78.84	0.12	20.81	79.07	1.50 p. m. water gage 1.8 inches.
U 771	2.30	Center	.06	20.80	.25	78.89	.06	20.85	79.09	2.15 p. m. water gage 1.4 inches.
U 772	2.30	Bottom	.86	19.65	.38	79.11	.86	19.72	79.42	2.30 p. m. water gage 1.75 inches.
U 773	2.45	Top	.05	20.85	.27	78.83	.05	20.91	79.04	2.40 p. m. water gage 1.75 inches; 7,700 cubic feet of air in circulation.
U 774	2.45	Bottom	.08	20.83	.27	78.82	.08	20.89	79.03	
U 775	3.00	Bottom	.06	20.87	.25	78.82	.06	20.92	79.02	3.00 p. m. water gage 0.10 inches.
U 776	3.00	Top	.10	20.76	.45	78.69	.10	20.85	79.05	
U 777	3.20	Top	.11	20.80	.44	78.65	.11	20.88	79.01	
U 778	3.20	Bottom	.07	20.83	.31	78.79	.07	20.89	79.04	
U 779	3.40	Top	.06	20.67	.92	78.35	.06	20.86	79.08	3.40 p. m. water gage 0.00 inches.
U 780	3.40	Bottom	.07	20.84	.32	78.77	.07	20.91	79.02	3.45 p. m. water gage 1.90 inches.
U 781	4.00	Top	.13	20.73	.57	78.57	.13	20.85	79.02	4.00 p. m. water gage 1.70 inches.
U 782	4.00	Center	.15	20.74	.37	78.74	.15	20.82	79.03	
U 783	4.00	Bottom	.11	20.83	.34	78.72	.11	20.90	78.99	
U 784	4.20	Top	.08	20.44	1.36	78.12	.08	20.72	79.20	
U 785	4.20	Center	.08	20.77	.23	78.92	.08	20.82	79.10	
U 786	4.20	Bottom	.07	20.73	.29	78.91	.07	20.79	79.14	4.30 p. m. water gage 0.05 inches; 1,900 cubic feet of air in circulation.
U 787	4.40									
U 788	4.40	Center	.07	20.73	.41	78.91	.07	20.82	79.11	
U 789	4.40	Bottom	.10	20.76	.37	78.77	.10	20.84	79.06	
U 790	5.00									
U 791	5.00	Center	.10	20.69	.55	78.66	.10	20.80	79.10	
U 792	5.00	Bottom	.07	20.76	.42	78.75	.07	20.85	79.08	
U 793	5.20									
U 794	5.20	Center	.09	20.70	.59	78.62	.09	20.82	79.09	
U 795	5.20	Bottom	.12	20.71	.52	78.65	.12	20.82	79.06	
U 796	5.40									
U 797	5.40	Center	.07	20.71	.62	78.60	.07	20.84	79.09	
U 798	5.40	Bottom	.09	20.68	.53	78.70	.09	20.79	79.12	
U 799	6.00	Top	.10	20.24	2.39	77.27	.10	20.74	79.16	
U 800	6.00	Center	.12	20.66	.62	78.60	.12	20.79	79.09	
U 801	6.00	Bottom	.07	20.67	.61	78.65	.07	20.80	79.13	
U 802	6.20	Top	.10	20.19	2.84	76.87	.11	20.78	79.11	
U 803	6.20	Center	.11	20.67	.56	78.66	.11	20.79	79.10	
U 804	6.20	Bottom	.10	20.73	.52	78.65	.10	20.84	79.06	
U 805	6.40	Top	.12	20.64	.89	78.35	.12	20.82	79.06	
U 806	6.40	Center	.13	20.68	.58	78.61	.13	20.80	79.07	

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U 807	6.40	Bottom	.10	20.77	.52	78.61	.10	20.88	79.02	6.45 p. m. water gage increased from 0 to 1.60 inches.
U 808	7.00	Top	.08	20.37	2.22	77.33	.09	20.83	79.08	7.00 p. m. water gage 1.90 inches; 8,500 cubic feet of air in circulation.
U 809	7.00	Center	.09	20.74	.46	78.71	.09	20.84	79.07	7.05 p. m. water gage 1.95 inches.
U 810	7.00	Bottom	.09	20.78	.44	78.69	.09	20.87	79.04	
U 811	7.20	Top	.13	20.48	1.15	78.24	.14	20.72	79.14	
U 812	7.20	Center	.09	20.72	.40	78.79	.09	20.80	79.11	7.20 p. m. water gage 1.75 inches.
U 813	7.20	Bottom	.07	20.69	.33	78.91	.07	20.76	79.17	
U 814	7.40	Top	.11	20.57	1.01	78.31	.12	20.78	79.10	7.40 p. m. water gage 2.10 inches.
U 815	7.40	Center	.11	20.61	.47	78.81	.11	20.70	79.19	
U 816	7.40	Bottom	.08	20.71	.31	78.90	.08	20.77	79.15	
U 817	8.00	Top	.11	20.71	.43	78.75	.11	20.80	79.09	
U 818	8.00	Center	.09	20.75	.29	78.87	.09	20.81	79.10	
U 819	8.00	Bottom	.15	20.66	.27	78.92	.15	20.72	79.13	8.10 p. m. water gage 1.80 inches.
U 820	8.20	Top	.17	20.44	1.06	78.33	.18	20.66	79.16	
U 821	8.20	Center	.21	20.58	.32	78.89	.21	20.65	79.14	
U 822	8.20	Bottom	.10	20.70	.27	78.93	.10	20.76	79.14	8.30 p. m. water gage 2 inches.

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TABLE 8.—*Analyses of mine air samples collected in entries b and c and in crosscut d, in a mine in Franklin County, Ill., showing changes due to interrupted ventilation.*

Laboratory No.	Position in section.	Time, p. m.	Analyses of samples as received.				Analysis of sample methane free.		
			Carbon dioxide (CO_2).	Oxygen (O_2).	Methane (CH_4).	Nitrogen (N_2).	(CO_2).	(O_2).	(N_2).
Samples collected in parallel entry *b*:			*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
U. 828	Top at right	3.40	0.13	20.33	1.42	78.12	0.14	20.62	79.24
U. 825	Top at left	3.40	.08	20.36	2.07	77.49	.09	20.79	79.12
U. 826	Center	3.40	.06	20.76	.33	78.85	.06	20.83	79.11
U. 827	Bottom	3.40	.10	20.78	.36	78.76	.10	20.86	79.04
Samples collected in parallel entry *c*:									
U. 829	Top	3.40	.10	20.28	2.52	77.10	.11	20.80	79.09
U. 830	Bottom	3.40	.10	20.78	.22	78.90	.10	20.82	79.08
U. 837	Top	5.30	.12	19.94	3.72	76.22	.13	20.72	79.15
U. 831	Bottom	6.10	.11	20.68	.40	78.81	.11	20.76	79.13
U. 832	Top	6.10	.32	19.62	3.72	76.34	.33	20.38	79.29
Samples collected in last open crosscut *d*:									
U. 823	Top	2.25	.05	20.87	.19	78.89	.05	20.91	79.04
U. 824	Bottom	2.25	.04	20.83	.18	78.95	.04	20.87	79.09
U. 833	Average	7.30	.10	20.73	.29	78.88	.10	20.79	79.11
U. 834	.....do	7.30	.06	20.75	.26	78.93	.06	20.80	79.14
U. 836	.....do	8.15	.07	20.74	.22	78.97	.07	20.78	79.15
U. 835	.....do	8.30	.07	20.79	.20	79.94	.07	20.83	79.10

NOTE.—Samples U. 834 and U. 836 were taken with patented stopper bottle and rubber bulb. All other samples were taken with vacuum bottles.

TABLE 9.—*Percentages of methane at faces of entries a, b, and c, and last open crosscut d, in a mine in Franklin County, Ill.*

Time, p. m.	Percentage of methane in section at—		
	Top.	Center.	Bottom.
Entry *a* (see Table 7):			
2.30	0.29	0.25	0.38
2.45	.27	.....	.27
3.00	.45	.....	.25
3.20	.44	.....	.31
3.40	.92	.....	.32
4.00	.57	.37	.34
4.20	1.36	.23	.29
4.40	[a] 1.56	.41	.37
5.00	[a] 1.77	.55	.42
5.20	[a] 1.98	.59	.52
5.40	[a] 2.19	.62	.53
6.00	2.39	.62	.61
6.20	2.84	.56	.52
6.40	.....	.58	.52
7.00	2.22	.46	.44
7.20	1.15	.40	.33
7.40	1.01	.47	.31
8.00	.43	.29	.27
8.20	1.06	.32	.27
Average	1.01	.44	.39
Entry *b* (see Table 8):			
3.40 Left	2.07	.33	.36
3.40 Right	1.42		
Entry *c* (see Table 8):			
3.40	2.52	.....	.22
5.30	3.72	.....	.....
6.10	3.72	.....	.40
Last open crosscut *d* (see Table 8):			
2.25	.19	.....	.18
7.30	.....	[b] .29	.....
7.30	.....	[b] .26	.....
8.30	.....	[b] .20	.....
8.15	.....	[b] .22	.....

[a] Estimated. [b] Across section.

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DISCUSSION.

Referring to Table 9 and figure 5, the first samples taken at 2.30 p. m. in the entry *a* and under normal ventilating conditions show the methane uniformly diffused and in only slightly greater amount than in the air current in the crosscut *d*. At this time the temperature of the air of the entry was 60° F. and the relative humidity was 60 per cent. The uniform diffusion continued until 2.40 p. m., when the fan was stopped. The samples from the top of the entry then increased in methane content until at 3.40 p. m., when the fan was started, the percentage at the roof had trebled. Almost as soon as the fan started there was a quick drop from 0.92 per cent to 0.57 per cent. Soon after the fan had stopped again a sample from the top analyzed 1.36 per cent methane. The roof samples collected between 4.40 and 5.40 p. m. were lost in the course of manipulation, and the curve in figure 5 for this period is estimated on the assumption of a regular increase between the known points for 4.40 p. m. and 6 p. m. At 6.20 p. m., or 2 hours and 20 minutes after the fan had stopped, the methane in the top sample reached 2.84 per cent, as compared with 0.56 and 0.52 per cent for the center and bottom samples, respectively. The fan was started at 6.40 p. m., and in about an hour the methane content of the top sample had dropped to about 1 per cent.

Analyses of the several samples taken in entries *b* and *c*, Table 9, show marked stratification of the methane at the top of the sections, the highest percentage being 3.72 at 6.10 p. m. in entry *c*.

Samples taken in the last open crosscut *d*, Table 9, show the percentages in the ventilating current at the times noted and may be used as a base from which to indicate the methane accumulation in entry *c*. For this reason they have been added to figure 5, where they appear as the lowest points.

In general, the gases in entry *a*, which were perfectly diffused at the beginning of the test, began to stratify as soon as ventilation was stopped. Starting the fan at 3.40 p. m. quickly aided diffusion, and stopping it from 4 p. m. till 6.40 p. m. greatly increased the tendency the methane to stratify. After 6.40 p. m., when ventilation was restored, diffusion began again quickly. Comparison of these results with those from the mine in Montgomery County plainly shows the influence of the better ventilating current in more quickly causing diffusion of the stratified methane. Moreover, as the gas feeders were probably at the top of the section, the stratification here of methane to the danger point in a short time is more noticeable than in the Montgomery County mine tests, where gas feeders were also at the bottom of the section.

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TESTS IN A MINE IN VIGO COUNTY, IND.

In cooperation with the State mine inspection department, a test was made in a shaft mine working the No. 5 coal seam in Vigo County, Ind. The mine was in the early stages of development and only a few rooms had been turned, but shot firers had already been injured from coal-dust explosions. Samples of air were collected at the face of one of a pair of parallel entries 35 feet inby the last open crosscut through which the air was passing. After the first samples had been taken, a canvas brattice was hung in this crosscut in such a manner as to reduce the open area to about 1 square foot. This allowed only a small quantity of air to pass and produce conditions of partly interrupted ventilation in the entry under test.

Table 10 lists the analyses of the samples of mine air taken in this entry. The tests lasted from 3.30 p. m. till 4.30 p. m., and the last open crosscut was bratticed immediately after the first samples were taken. During the hour this entry was practically without ventilation, no change in the oxygen or carbon dioxide percentage of the air could be detected. The accumulation of methane was pronounced; in Table 11 the percentages are listed by themselves according to time and place in the section sampled. Under normal ventilation, the methane content of the air at the entry face was 0.27 per cent and the gas was diffused uniformly throughout the section. Stratification of the gas began after the ventilating current had been interrupted, and within 40 minutes the methane content at the roof was 1.02 per cent, an increase of nearly 400 per cent. Had shots been fired in this entry under these conditions, the hazard of an explosion being propagated would have been much greater than under normal conditions. During this same time the samples taken from the bottom of the entry showed little increase in methane content.

TABLE 10.—*Analyses of mine air samples collected at the face of an entry in a mine in Vigo County, Ind., showing changes due to interrupted ventilation.*

Laboratory No.	Position in section.	Time, p. m.	Temperature, °F.	Humidity, per cent.	Barometer, inches.	Analysis of sample "as received."				Analysis of sample methane free.		
						Carbon dioxide (CO_2).	Oxygen (O_2).	Methane (CH_4).	Nitrogen N_2.	CO_2.	O_2.	N_2.
						Pr. ct.	*Pr. ct.*	*Pr. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
U. 852	Top.....	3.30	61	84	29.40	0.19	20.66	0.27	78.88	0.19	20.72	79.09
U. 853	Bottom.....	*a*3.30	61	84	29.40	.13	20.71	.27	78.89	.13	20.77	79.10
U. 854	.....do.....	*a*3.50	61	84	29.40	.19	20.65	.32	78.84	.19	20.72	79.09
U. 856	Top.....	4.10	60.5	86	29.41	.16	20.55	1.02	78.27	.16	20.76	79.08
U. 857	Bottom.....	4.10	60.5	86	29.41	.11	20.74	.30	78.85	.11	20.80	79.09
U. 859	.....do.....	4.30	60.5	86	29.41	.18	20.65	.35	78.82	.18	20.72	79.10

a Ventilation interrupted between 3.30 and 3.50.

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TABLE 11.—*Percentages of methane at the face of an entry in a mine in Vigo County, Ind.*

Time, p. m.	Percentage of methane in section at—		Remarks.
	Top.	Bottom.	
3.30	0.27	0.27	Crosscut open.
3.50		.32	Crosscut brattiсed and ventilation of entry interrupted.
4.10	1.02	.30	
4.30		.35	

GENERAL CONCLUSIONS.

The tests described for the entry and for the room in the mine in Montgomery County, Ill., for the entry in the mine in Franklin County, Ill., and for the entry in the mine in Vigo County, Ind., bring out the following points:

(1) The greatest decrease in oxygen content in the mine air was about one two-hundredths of the normal amount only, a quantity that would have no appreciable influence on the explosibility of gas and coal dust, and this small decrease was not noticeable until the ventilation had been stopped for two and one-half hours.

(2) No increase in carbon dioxide content that would in any way hinder the ignition of gas or dust, or lessen the liability of propagation of an explosion was noted in any of the analyses taken under conditions of interrupted ventilation.

(3) When three facts are considered, (1) that in none of the places sampled had gas been reported, (2) that the mines are considered nongaseous, and (3) that open lights are in common use in them, the rapidity with which methane accumulated under interrupted ventilation is noteworthy.

(4) It is a well-known chemical law that any two gases, as air and methane, in contact always diffuse more or less rapidly through each other and will finally reach a uniform mixture. However, the idea is common that methane, being lighter than air, rises through air like oil through water, and remains near the roof in an unmixed condition until swept away by the ventilating current. The tests illustrate this law of diffusion and disprove the common idea of the separation of methane from air. Methane issuing from feeders at the bottom of a section diffused more readily than from feeders at the top. The gas issuing near the bottom rises through the air because of its low specific gravity in comparison with air, and its passage constitutes a gentle current that mixes it with the air and aids diffusion. Methane issuing from near the top becomes mixed with the air, in the absence of air currents, only by diffusion, therefore the tendency to stratify is greatest there. Evidently once the gas issuing at any section is diffused in the air, it does not stratify again, but interruption of the ventilation may permit new volumes of gas to stratify.

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(5) It appears that if the mine air is in motion, gas stringers or currents coming from the strata are broken up and diffused more quickly and stratification is not so evident. A simple comparison is the smoke from a lighted cigar, which in a room where the air is still will rise to the ceiling of the room and stratify there. Just as a wave of the hand will so disperse and diffuse the ascending smoke column that it will not reunite, so methane currents disperse and remain dispersed after being disturbed by air currents.

As a corollary, a single large body, current, or volume of methane is diffused more slowly in air than equal volumes distributed among several small currents. Similarly, smoke from several small stacks is more quickly diffused than an equal volume from one large stack, a principle that is utilized in diffusing smelter smoke.[a]

The methane percentages in the samples taken at the center of the sections are low and show only slow and regular changes. The methane here in most cases is thoroughly diffused.

(6) A room or entry face ventilated merely by the air current sweeping past the room neck or through the last cross cut is ventilated by eddy currents only. Although this eddy current may aid diffusion of the gas, its influence in these not uncommon conditions tested in the Montgomery County room and entry face is so feeble that several hours are required to break up, diffuse, and sweep away the stratified gas. In the entry in the mine in Franklin County the better ventilating conditions cut down appreciably the time needed for this diffusion.

(7) The rapid stratification and increase of methane at the top of the sections tested indicate that had the ventilation been interrupted for a few hours longer the methane content of the air would have reached 5 or 5.5 per cent, the lower inflammable limit. It is emphasized here again that the tests were made in sections not considered gassy and in which gas could not be detected with a safety lamp just before the tests.

(8) Eddy currents of air ventilate only by stirring the air and in this way hastening diffusion. They aid in preventing the accumulation of gas at the top of a section, and also cause any such accumulations to mix more readily with the air. After the air current has been interrupted and stratification of the gas has taken place, ventilation by eddy currents is relatively inefficient, at least for several hours.

(9) It is not the average proportion of methane in the air of a section that is indicative of the dangers, but the point of greatest concentration. Although it is well known that this point commonly is near the roof, the fact that certain bottom samplings showed high methane content is noteworthy.

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[a] Fulton, C. H., Metallurgical smoke, Bull. 84, Bureau of Mines, 1915, p. 82.

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(10) The accumulation of even 1 or 2 per cent of methane in the still air, such as actually took place in the short time the tests were in progress, would have marked effect in the liability of propagation of a coal-dust explosion originating in this atmosphere.

(11) In application, the tests show the possible danger from failure to restore promptly ventilation that has been interrupted in any section of a mine, and the necessity of withdrawing the men there and not allowing their return until tests have been made for gas. The increased liability of explosions being propagated makes necessary extra precautions to insure that no shots are fired in these places until ventilation has been fully restored.

SLOWING THE VENTILATING FAN DURING SHOT FIRING.

The tests of methane accumulation that are described on pages 18 to 24 have their principal application to practical mining problems in throwing new light on the much discussed question of slowing or stopping the mine fan during or previous to shot firing. In general, it is or has been the custom at many mines in the central coal field and in other districts to interrupt partly or wholly the ventilating current during and often for one or two hours previous to shot firing.

The practice has been defended by the claims presented below:

1. Still air will not propagate an explosion readily.

2. When the fan is running, the intake side of the mine, because of the stronger air current there, is the one more susceptible to explosion.

3. In a mine without ventilation the air quickly loses oxygen and gains carbon dioxide, and this change is aided by the products of combustion from the shots fired until the danger of explosions being propagated is greatly reduced.

4. Where air is traveling through the mine at high velocity there is a greater quantity of air in the mine at any one time, consequently a greater chance for propagation of explosions.

5. In still air inflammable dust disturbed by one blast is not liable to be carried to any place where another blast may ignite it easily.

Some of these reasons are not valid and others hold good in particular cases only. Work by the Bureau of Mines [a] at the experimental mine at Bruceton, Pa., has definitely shown that the presence of only 1 or 2 per cent of gas in mine air increases decidedly the liability of propagation of an explosion. Thus a coal dust containing 60 per cent incombustible matter would not propagate without gas in the air, but would propagate with 1 per cent of methane present, and a dust with 65 per cent incombustible would not propagate with 1 per cent methane, but would with 2 per cent. The tests in

[a] Rice, G. S., and Jones, L. M., Methods of preventing and limiting explosions in coal mines: Tech. Paper 84, Bureau of Mines, 1915, p. 7.

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this paper on methane accumulations have shown how quickly such small percentages of methane may accumulate when ventilation is interrupted. From these facts the conclusion must be drawn that slowing a fan during shot firing in mines where methane may accumulate, even to a small degree, is an extremely hazardous practice and the danger far outweighs any possible gain. The methane in the air may be likened to the kindling that ignites easily in a fire and in turn ignites the main body of fuel.

Other tests by the Bureau of Mines have proved that an explosion may start from a single shot in a quiet atmosphere as well as in a strong current, and that the explosion may travel either with or against the air current. The direction depends upon the nature of the coal dust in the path of the explosion and upon other conditions. For example, if there is a preliminary disturbance of the coal dust that causes it to be in suspension in the air, such as would result from rapid shot firing, or a local explosion of a body of gas, the presence of this dust greatly favors the propagation of an explosion.

Many new mines have suffered from frequent explosions originating through shot firing, especially in passageways where the ventilating current has been strong and continuously cold for a number of days. These explosions often have been of enough violence to damage the fan or fan housing and to destroy underground doors and stoppings. In some new mines the underground doors and the fan doors are opened before shot firing, with a view of permitting any explosion to expand with minimum resistance and thus lessen property damage. This practice of course effectively interrupts all ventilation. In a new mine only a comparatively small number of shots are fired and the time occupied is therefore short. The chances of increase of methane to a dangerous percentage are therefore less than when the mine becomes further developed and the ventilation interrupted for a longer time.

In these new mines where the area ventilated is small and where the stoppings are few in number and well constructed there is little chance for the air to short-circuit. The fan was probably designed with a view to efficient ventilation when the mine workings extend 5,000 to 10,000 feet in each direction from the bottom of the shaft. The tendency is to overventilate the new mine, sending in more air than is needed, with the consequence that the velocity is high and the air, in winter, is cold. As a result, all moisture is quickly removed from the dust in the mine, in spite of periodic sprinkling, and the dust enters its most explosive condition. Even in the more developed mines, shot firers claim that in cold weather the reports from shots near the colder intake air current are frequently much louder than the reports from shots in the warmer return; this would indicate that there was local ignition of coal dust from the shots on the intake.

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This peculiarity is easily explained as due to the coal dust being much drier on the intake, in the colder sections of the mine, because it is here that the air, becoming rapidly warmed, has the greatest tendency to absorb moisture. Mistaking cause for effect, many believe it is the circulation of cold air at the time of shooting that is responsible for such explosions. A change in blasting practice by the elimination of long-flame explosives and greater attention to the dust hazard would be of greater real value than stopping the fan.

Care to avoid excessive ventilation in new mines all the time will aid by allowing the dust to retain moisture for a greater length of time. In developed mines, an air velocity of more than 1¾ feet a second is rarely maintained within reach of the flame of a normal shot, and there is no need of using a greater velocity in new mines.

The contention that interrupting the ventilation quickly causes a decrease in the oxygen content of the air and an increase in the carbon dioxide content and thus renders coal dust or gas less liable to ignition is disproved by the air analyses listed on pages 16 to 28. In the average mine in the districts studied no appreciable change in quantity of oxygen or of carbon dioxide in the air took place in the period of time usually covered by the interruption of ventilation preceding and during shot firing.

The claim that in the mine more air is present when traveling at considerable velocity than when still, is disproved by a simple calculation. Practically the only difference in the amount of air in the mine at any one time results from the change in the density of the air caused by the difference in pressure that forces the air through the mine. A difference in pressure of 2 inches water gage between downcast and upcast would affect the amount of air in the mine only about 0.5 per cent or one-two hundredths. This is less than one-sixth of the variation in amount of air in the mine that would be caused by a change in atmospheric pressure of 1 inch in the barometer. As such changes in barometric pressure are frequent, it can be seen how relatively unimportant is any change in quantity of air in the mine due to ventilation pressure. Variations in temperature at the working faces in a well-developed mine are small, possibly not exceeding one degree, and any change in amount of air in a mine due to this cause need not be considered here.

Finally there remains only the danger from dust suspended during shot firing in a moving air current as against a still air current. To determine the conditions under which shots are fired, a record was kept by the authors of the time and number of shots fired during several days at a mine in one of the districts under study. At this time two shot firers were employed, and an average of 160 shots were fired each evening. The shot firers entered the mine at 3.30 p. m. at the end of the day shift, and in the 11 days for which records

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were kept, remained in the mine for 1 hour and 27 minutes to 3 hours and 45 minutes. Thirty minutes were necessary altogether to go to the first working place and return from the last working place. If this period is deducted from the total time spent in the mine, the remainder gives the total time spent in firing shots. Dividing this by 160 gives the number of shots fired per minute. The record is detailed in Table 12.

TABLE 12.—*Rate at which shots in a mine were fired by two shot firers.*

Date	Time spent in firing shots.	Approximate number of shots per minute.	Date.	Time spent in firing shots.	Approximate number of shots per minute.
	H. m			*H. m.*	
Mar. 10	1 30	1.1	Mar. 22	2 45	0.5
11	1 40	.9	24	3 45	.3
13	2 35	.6	25	2 35	.5
17	1 27	1.1	28	3 00	.5
18	1 27	1.1	29	2 45	.5
20	3 5	.4			

In some places in a mine, more fuses are lighted in a minute than is shown by the table. As the fuses are not of exactly the same length, a considerable number of the shots, as is indicated by the reports, go off together or in rapid succession. In this way it is possible for two shots in a room neck to explode perhaps 10 seconds before the shots at the face of an entry, and if the air current were sweeping past the room neck toward the entry face, the dust, with the possible powder smoke, might be carried so that a badly placed shot in the entry face would ignite it. In this way an explosion might be propagated without the presence of methane. That such a condition could arise from excessive air current alone is extremely unlikely, and danger from such a source may be lessened easily by a change in blasting practice. The use of permissible explosives, increase in the time between shots, regulation of the length of fuses and firing successive holes against the air current are more effective preventives of this danger than destroying ventilation. Perhaps the simplest precautions that would improve conditions would be to fire one shot in a section at a time by electricity, or if fuses are used to cut them all to one length, that they may go off successively as lighted. It is well to point out here that the use of black blasting powder in these mines is dangerous even under the closest inspection and most stringent regulations.

As final proof of the danger of slowing the fan during shot firing, in districts where this practice is tolerated there have been more explosions than in any other districts in the United States.[a] Fur-

[a] Rice, G. S., and Jones, L. M., Methods of preventing and limiting explosions in coal mines. Tech. Paper 84, Bureau of Mines, 1913, p. 64.

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thermore, of 17 explosions occurring at shot-firing time in mines in Indiana and Illinois and investigated by the authors, 16 were in mines where it was the practice to slow the fan before or during shot firing. In the other case no definite information was available. Some of the explosions were widespread and extremely violent, but attracted little general attention because of the small number of men killed or injured, the shot firers being alone in the mine.

It must be regarded as a proven fact, that if methane is present, even in small percentages, interrupting ventilation in a mine means the certain increase of a known danger for the elimination of a less serious one.

CAUSES OF METHANE ACCUMULATIONS IN MINES.

The tests described on pages 12 to 31 have demonstrated that dangerous percentages of methane may accumulate suddenly even in mines usually considered nongaseous under normal ventilating conditions. The hazards from the accumulations at shot-firing time have been pointed out on pages 31 to 35. The dangers from ignition of a methane accumulation by an open lamp, spark or other source of heat are well known. Because of these dangers, the conditions in a mine favorable to the accumulation of methane will be considered in detail.

Methane may accumulate to dangerous and unusual quantities in a mine from the following causes:

(1) Sudden liberation of methane from seams, cracks, or other feeders in greater volume than the usual ventilating current can diffuse and sweep away.

(2) Emission of methane from inaccessible and abandoned workings, as a result of either an increase or decrease in the pressure of the ventilating current.

(3) Local accumulations of methane resulting from any interruption of the normal ventilating current.

SUDDEN LIBERATION OF METHANE FROM SEAMS, CRACKS, OR OTHER FEEDERS IN GREATER VOLUME THAN THE USUAL VENTILATING CURRENT CAN DIFFUSE AND SWEEP AWAY.

To meet, in mining, so-called methane feeders or blowers in cracks or seams, is common in both bituminous and anthracite coal mines. The causes of these outbursts of gas, and of methane emanations in general as related to rock strata and mining conditions, are discussed in Bureau of Mines Bulletin 72.[a]

An illustration of these sudden outbursts in the central district is furnished by a mine in Illinois working seam No. 5, where a gas blower was opened while the coal was being undercut with a machine at

[a] Darton, N. H., Occurrences of explosive gases in coal mines, Bull. 72, Bureau of Mines. 1915, 248 pp.

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the face of an entry. Eight days later 40 cubic feet a minute of methane were still issuing from the face of this entry and from the parallel entry. This amount was calculated by measuring the volume of air ventilating these entries, and by analyzing samples of the air taken on the intake and on the return.

In a mine in Indiana a mining machine cut into an old prospecting bore hole. Five days later a Burrell methane indicator showed 0.3 per cent of methane in the air current, 30 feet inby the hole, although 30 feet outby the hole there was no indication of methane.

EMISSION OF METHANE FROM INACCESSIBLE AND ABANDONED WORKINGS THROUGH A CHANGE OF PRESSURE IN THE VENTILATING CURRENT.

Emission of methane from inaccessible or abandoned workings may result from any of the following causes:

(*a*) Change in speed of fan.

(*b*) A door or other ventilating regulator left open or closed, contrary to its normal condition.

(*c*) Local air currents caused by trips of cars moving at high speed.

(*d*) A change in barometric pressure.

Methane often accumulates in inaccessible places in a mine, as behind or over falls or back of stoppings, and also in abandoned workings where the ventilation may be poor. When constant ventilating pressure is maintained in the mine the gas probably continues to diffuse gradually into the air current. A change in air pressure from any of the causes named above may allow a considerable volume of gas to be drawn or forced into the air current.

In a mine in Illinois, several men going into old workings to recover equipment, left open a door between two entries and allowed the air to short-circuit. Owing to the resulting change in the ventilating pressure a body of gas issued suddenly from the old workings into a working place that shortly before had been pronounced safe. It became ignited by an open light and 40 men were imperiled for a time by being trapped behind the afterdamp. The cause of the mine accident given on page 10 is a further example of the movement of a body of methane under changed ventilation conditions.

As an experiment, while in a mine one of the authors held a safety lamp close to a crack in a cement stopping, behind which was known to be a considerable body of methane. When the ventilating current was normal no gas could be detected, but as often as a certain door in that section of the mine was opened, the gas poured through the crack in quantity sufficient to be detected by the safety lamp. Evidently the balance or equilibrium between bodies or currents of air in the mine is more delicate and more easily disturbed than is commonly supposed.

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A more serious, and often overlooked, factor in disturbing the balance of mine ventilation is a fast-moving trip of cars. When mine cars were small and hauled slowly by mules, their interference with ventilation was relatively negligible. Modern cars that nearly fill the entry, drawn by electric locomotives at high rates of speed, create currents and eddies of air that tend to drive or suck out methane from places where it has accumulated. Many fire bosses have spoken of the sudden appearance and disappearance of a body of gas that seemed to advance and recede, according to the direction of the rapid movement of trips of cars in the vicinity.

Many discussions have covered the effect of barometric pressure on methane emanations and accumulations. As the authors have no new facts to present on this subject, an example is given that illustrates the effect of a change in barometric pressure on the air in closed or abandoned workings, or on gas issuing into the mine from any source. One inch decrease of barometric pressure causes a given volume of air or any gas to expand about one-thirtieth. Suppose that in a mine worked in a 6-foot bed, an abandoned section has a worked-out area of 10 acres. Then the volume of this space would be $43,560 \times 10 \times 6 = 2,613,600$ cubic feet. A fall of barometer equal to 1 inch would expand this volume by $\frac{2,613,600}{30} = 87,120$ cubic feet, and this 87,120 cubic feet of air and gas would leave the old workings during the fall of the barometer. Therefore a low barometer must disturb the balance of pressure that has been established between the air current and the issuing gas or gas mixtures, and must favor the emission of methane, whether from feeders or from old workings.

LOCAL ACCUMULATIONS OF METHANE FROM INTERRUPTIONS OF THE NORMAL VENTILATING CURRENT.

Methane that issues into the mine workings and normally is diffused by the ventilating current may accumulate under interruptions of ventilation from any of the causes following:

(*a*) Stopping or slowing the ventilating fan.

(*b*) Blocking the airways.

(*c*) Failure of doors, stoppings, and other appliances used to direct and control ventilation.

(*d*) Lack of frequent break-throughs or of brattices to conduct the ventilating current closer to the working face.

STOPPING OR SLOWING THE FAN.

The ventilating fan may be accidently slowed or stopped by the failure of the belt or other power transmission or connection, by a decrease in steam pressure or electric voltage or by direct failure of the engine, motor, or fan itself. The fan may be purposely slowed

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or stopped to facilitate observation of the nature of gas in abandoned panels or of gas coming from behind walls in fire areas. At some mines the fan is stopped during the night and at any other time when no men are in the mine. The fan also may be slowed or stopped during shot firing, as has been discussed on pages 31 to 35.

In general, more attention should be given the mechanical plant used to produce ventilation in a mine, and enough supplies should be kept on hand for repairs in case of a breakdown. Stopping or slowing down the fan should be considered a more serious happening than is actually the case at many mines.

BLOCKING THE AIRWAYS.

The airways of a mine may become blocked, either partly or completely by the falling of the roof, the squeezing of a pillar, or the heaving of the bottom. Plate I, *A*, shows a fall of roof large enough to prevent the free circulation of air through a section of a mine. Plate I, *B*, shows a heaving bottom that restricted the sectional area of a 6-foot entry enough to interfere with ventilation. About 3 feet of the bottom had to be taken up to obtain car clearance when this entry was used later as a haulageway.

Gob is sometimes thrown carelessly in front of the last open cut through in a room or in an entry and thus retards the air current. In freezing weather ice may form in the intake air passages, partly close them, and thus reduce the volume of air in circulation. A terrible explosion some years ago in a bituminous coal mine in Pennsylvania is attributed to such ice formation, as restriction of the air current permitted accumulation of methane, and afterwards it was ignited.

Supplies may be unloaded and stored on important air courses, materially reducing their area and consequently the volume of air that can pass. Continuously poor ventilation results where there are narrow entries, whether driven narrow or made so by piling gob along the sides. An entry may be so low that the loaded car almost rubs the roof. In a mine in Pennsylvania an explosion was attributed to the ignition of the body of methane that had accumulated in a room because the ventilation was stopped when a loaded car was left in the small room neck. A trip of cars becoming wrecked in a small airway also offers opportunity for restriction of ventilation in that part of the mine.

FAILURE OF DOORS, STOPPINGS, AND OTHER VENTILATION APPLIANCES.

Disarrangement and consequent failure of doors, regulators, stoppings, overcasts, brattices, or other ventilation-controlling devices in a mine may be caused by roof or floor movements, either from falls of roof, a squeeze or creep, although a gob stopping often packs more

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A. FALL OF ROOF PREVENTING FREE CIRCULATION OF AIR THROUGH A SECTION OF THE MINE.

B. A HEAVING BOTTOM IN A 6-FOOT ENTRY.

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firmly as the roof weight settles on it. The crushing of pillars may break stoppings and cause them to leak air. Fires may burn through or around stoppings or pillars, or may destroy them. Doors may be broken by careless driving or trapping, or by run-away trips or made useless through defective hinges or may not close because of accumulations of loose coal or dirt.

In a mine in Alabama methane accumulated during an interruption in ventilation caused by delaying needed repairs to a broken door; the men in that part of the mine were not withdrawn and a serious explosion resulted. A similar explosion resulted in a mine in Ohio when a brattice man did not put up a temporary brattice while erecting a new door. This short-circuiting of the air allowed a body of methane to accumulate, and when ventilation was restored it was driven out on an entry, and accidently ignited. Many other explosions from similar causes might be cited.

Coal dust and methane explosions usually destroy the stoppings, doors, overcasts, and brattices in the section of the mine traversed, and improper and heavy blasting of coal, roof, or bottom may be equally destructive locally. Damage from these causes should be repaired without delay. One of the authors was told by the mine examiner at a certain mine that no gas was present in the section of the mine under inspection; but on the main entry, 1,000 feet from the face, an explosive mixture of methane and air was encountered that gave no warning of its presence until it flamed in the safety lamp. The ventilation had become deranged through broken stoppings and new stoppings were being built to restore it. The gas seemingly had moved out on the main entry without diffusing.

Trips of cars passing through important single doors frequently cause short circuits of the air. Every door should close automatically as soon as a trip has passed through. If doors important to the ventilating system are used frequently, or if the trips passing through are long, two doors should be placed a distance apart greater than the length of the trip, and thus form an air lock. A latch or other device for holding open a door should not be permitted, as the use of such devices often results in a door being left open indefinitely. A car or a trip of cars should not be allowed to stand on the track in such a position as to prevent a door closing, but the car should be moved or a trip should be split so as to allow the door to close immediately.

The most frequent cause of interrupted ventilation in a mine is leaving doors or regulators open either for convenience or through carelessness. In one instance, a trip of cars was left standing in an automatic door for 25 minutes while the locomotive gathered cars from another panel. Forty men were at work in the split of air thus short-circuited. In another mine a driver left a door open for over

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an hour while the writer was in the same section of the mine. The driver stated that when going in for his trip he left the door open because the mule would not open it for him when he came out. The door was seldom closed when the driver was hauling regularly, as the track was down grade outby and in order to close the door he would have had to stop when coming out with the trip. The men working on this split of air stated that the ventilation was poor, but did not complain to the mine manager for fear that the driver would be discharged. Mine doors that are found open from any cause should be closed at once, unless they are marked to indicate that they have been left open intentionally.

A number of explosions have happened through a mining machine or car tearing down the canvas in an entry beyond the last crosscut. For example, in a mine in Pennsylvania in 1916 a trip of cars tore down a canvas brattice in a crosscut. This caused nearly all the air there to short-circuit and allowed methane to accumulate in another section of the mine with the result that an explosion took place, killing eight men.

FAILURE TO DRIVE FREQUENT BREAK-THROUGHS OR TO USE BRATTICES TO CONDUCT THE VENTILATING CURRENT CLOSER TO THE WORKING FACE.

Working places in mines are often advanced so far beyond the effective air current that methane may accumulate at the face. Driving cut-throughs at more frequent intervals or a more general use of line brattices are effective means of avoiding this danger.

PREVENTING ACCIDENTS FROM METHANE ACCUMULATIONS.

As lack of adequate ventilation may permit methane to accumulate in a place where its presence is not detectable ordinarily, it is important that every one in a mine should seek to prevent any ventilating appliance from becoming or remaining out of order. In mines where methane is detected only occasionally, precautions are as necessary as in the more gassy mines. It is better to be overcautious than careless. Among the safety measures observed at different mines are the following:

1. An automatic recording water gage is used to indicate ventilating pressure and a barometer to indicate atmospheric pressure. These instruments should be installed on the surface where they can be read frequently by the superintendent, engineer, and foreman. A rise in water gage will indicate that the air path probably has been blocked by a fall of roof and a fall in pressure indicates that the air has been short-circuited. Either change may be favorable for the accumulation of methane. A low barometric pressure will permit gas that has accumulated in old workings to come out.

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2. The speed of the fan is kept constant throughout the 24 hours. Increasing the speed may drive gas from old workings. Decreasing the speed may allow the gas to be drawn out of old workings, and also to accumulate locally at its source.

3. When any change in the ventilating current is noticed, it is reported, the cause is investigated, and precautionary measures are taken. All men are withdrawn from any section of the mine affected by the deranged ventilation and are not permitted to return until the air current has been restored and a thorough examination has been made of the section.

4. Drivers and trappers are not permitted to leave open or prop open a door. The bratticemen are instructed to put up a temporary brattice when a door or a stopping has been wholly or partly destroyed and not repaired immediately. Even when a door or a stopping is replaced, a temporary stopping is put up, so that there will be no change in the normal ventilating conditions. The air courses, in the minds of some foremen, are the blood vessels of the mine, and they have the same care for the repair of a damaged mine door or stopping that they would have for the bandaging of a wound.

5. When it is necessary for men to pass frequently through a sliding regulator, a self-closing door is provided at one side of the regulator, so that it will not be necessary to rely on men who do not appreciate mining hazards to readjust the slide. If the first man of a party passes a regulator and relies on the men behind to adjust it, the last man may follow the example of the man preceding him and leave it open. Regulator slides are sometimes locked or nailed in the required position.

6. Safety lamps or permissible electric lamps exclusively are used in many mines in the Appalachian coal field and in some other districts. Explosions occur for the most part in mines where methane, although present, is not considered a menace and where open lights exclusively or some open lights and some safety lamps are used. In England, statistics covering a number of mines where safety lamps are in use and an equal number where open lights are used show that 90 per cent of the mine explosions happen in the open-light mines, and that the open lights are largely responsible.[a]

One coal company in Indiana has obtained approved electric cap lamps for all the miners in two of its mines. An agreement between the miners and operators was reached to permit their use, pending a final settlement at the signing of the next wage scale. These are perhaps the first mines in the Illinois-Indiana coal field to use approved electric cap lights. Their more general use might have pre-

[a] Rice, G. S., and Jones, L. M., Methods of preventing and limiting explosions in coal mines, Tech. Paper 84, Bureau of Mines, 1913 p. 64.

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vented a number of explosions in Illinois and Indiana mines.[a] Plate II, *A*, shows the interior of the lamp house at the Indiana mine.

7. Fencing off old and abandoned workings in mines, preferably with chicken wire, is an efficient means of preventing men with open lights entering them and does not interfere with ventilation. Plate II, *B*, shows a chicken-wire guard in an Illinois mine at the entrance to abandoned workings.

8. The use of permissible explosives is a valuable protection from the danger of small percentages of methane. These are being introduced gradually into many mines in Illinois and Indiana, especially in mines where methane may accumulate. About 20 per cent of all the coal mined in Illinois is blasted with permissible explosives.

9. The mines that have the most efficient ventilation are those where there is real cooperation between the superintendent and the mine foreman (mine manager). At these mines supplies needed to maintain ventilation are ordered far enough in advance to meet any ordinary emergency, and orders for the delivery of these materials are issued promptly on the request of those responsible for maintaining ventilation.

10. The proper use of rock dust in a mine will prevent an ignition of gas from causing a far-reaching coal-dust explosion. Although rock dusting has not been used in any mines in Illinois and Indiana, its use is being considered seriously. Finely ground rock dust is being used successfully in mines in several European countries, and at a few mines in the United States, notably in Pennsylvania. The Bureau of Mines, at its experimental mine at Bruceton, Pa., has shown that rock dust properly applied will effectually prevent the propagation of a coal-dust explosion, and that more rock dust must be used in order to prevent propagation of an explosion in workings that contain gas.

11. Finally, the State laws relating to ventilation are observed not only as a requirement of the State inspector but as an effective means of promoting greater safety.

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[a] As this bulletin goes to press, it is estimated that there are in use in the coal mines in the United States more than 100,000 "permissible" cap lamps.

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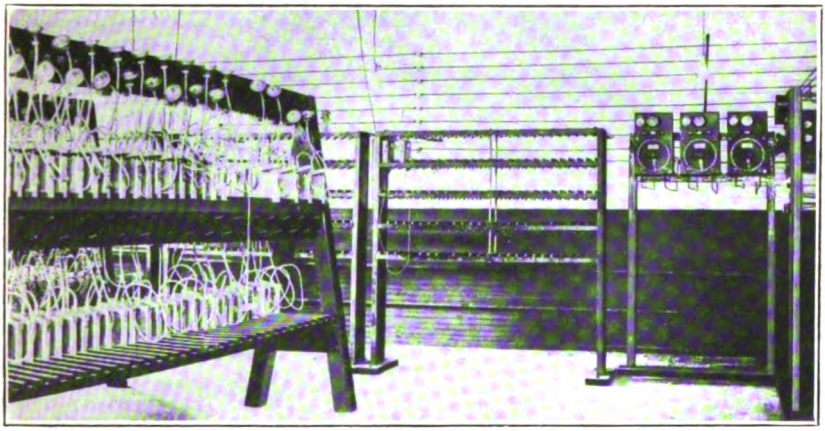
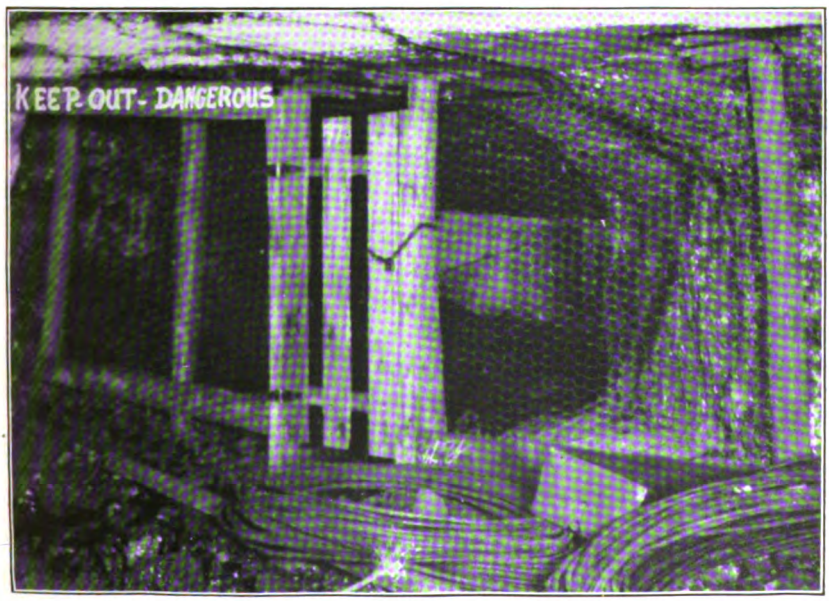


A. INTERIOR OF AN ELECTRIC LAMP HOUSE AT AN INDIANA MINE.



B. WIRE-NETTING GUARD, FENCING OFF OLD WORKINGS, IN AN ILLINOIS MINE.

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PUBLICATIONS ON COAL MINING.

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BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp., 10 pls., 12 figs.

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